Clean Version of the Specification

Schott AG

Unit for conductively heatable melting

CROSS-REFERENCE TO RELATED APPLICATIONS

5   This application claims the benefit under 35 U.S.C. §365
of International Application Serial No. PCT/EP/2004/011153
filed October 6, 2004, which claims the benefit of German
Application No. 103 46 337.2 filed on October 4, 2003.

10   BACKGROUND OF THE INVENTION

1.   Field of the Invention

The invention relates in general terms to a unit, in
15   particular a melting and/or refining unit and/or a
distributor system and/or a channel system, for conductively
heatable melts, and specifically to a unit for conductively
heatable glass melts.

20   2.   Description of Related Art
The production of glasses involves the formation of glass
melts to which thermal energy is supplied. This applies to
the process of melting down glass or glass charge cullet, as
well as subsequent process steps, such as for example
25   refining or homogenization. The thermal energy which this
requires can particularly efficiently be released directly in
the melt by means of the Joule effect.

Therefore, melting installations, in particular for

glassmaking, often use   electrodes which are immersed
in the liquid melt. Electric current is introduced into the
melt via the electrodes. The electrode unit in this case
comprises the electrode body and an electrode holder which
carries the electrode body. The electrode holder and the
electrode body are generally fixedly connected to one
another, for example by screw connection or welding. For its
part, the electrode holder is fixedly connected to the
external surroundings.

Electrodes are used immersed in the melt both in the base and
in the sides or from above. The form of electrode which is
most frequently used is the stick shape, since this is very
easy to push in further. Moreover, the stick-shaped electrode
offers the advantage that it is possible to exchange the
entire arrangement made of electrode holder and electrode
body even when the installation is running. In the case of
plate electrodes, by contrast, it is not possible to either
exchange the electrode or push it in further during
operation.

Above a certain temperature, glasses become electrically
conductive, so that at voltages up to approximately 1000 V,
sufficiently high currents can usually flow to heat the glass
melt using the Joule effect. In the melt, the current is
substantially transported by the ions of different mobility.
Standard frequencies for the conductive heating of melts are
50 or 60 Hz; frequencies of 10 kHz are used for high-quality
glasses, in particular optical glasses.

Fig. 1 illustrates a typical structure which illustrates how
the current is fed into the melt from outside the unit via an
electrode. The figure shows an excerpt from the wall of a

melting and/or refining unit having an electrode assembly.
The arrangement comprises a generally water-cooled electrode
holder, in which the actual electrode body is secured in a
suitable way. On the outside, the electrode holder is
5   connected to a heating circuit transformer via a cable. The
electrode is introduced into the melt through the wall, which
is constructed from refractory material. The distance, in the
longitudinal direction of the electrode holder or electrode
body, from the upper side of the electrode holder, facing the
10 melt, to that surface of the wall which faces the melt is
referred to as the setting depth. The setting depth is
determined according to the particular type of glass, in
particular its vitrification and crystallization properties,
as well as the required process temperatures and the
15 structure of the wall, in particular the thermal conductivity
of the materials used.

It is customary to use separate electrode bricks in which
there is a drilled hole for the electrode. The electrode
20 brick itself is inserted into the wall of the melting and/or
refining unit. A separate electrode brick offers the
advantage that the region around the electrode can be easily
observed from the outside. It is in this way possible to
quickly recognize cracks and glass leakages. If the thickness
25 of the brick is reduced by the glass melt on account of
corrosion, it is easy to apply forced cooling from the
outside, which efficiently cools that side of the electrode
brick which faces the glass and therefore reduces the
corrosion caused by the glass melt.

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Details can be found in the relevant specialist literature on
glass technology. The prior art is well documented, for
example, in the HVG training volumes "Elektroschmelzen von

Glas" [Electrical melting of glass] 1990 and "Wärmetransportprozesse bei der Herstellung und Formgebung von Glas" [Heat transfer processes in the production and shaping of glass] 2002.

5

The current, which is fed in from the outside from suitable matching transformers via feed lines, enters the glass melt from the electrode body in order to heat the glass melt by the Joule effect. The electrical power density $\rho_{el}(\vec{r})$ for the

10   entire arrangement comprising melt and wall, given the standard dimensions of the units and heating frequencies, can be calculated as:

$$P_{el}(\vec{r}) = \vec{J}(\vec{r}) \cdot \vec{E}(\vec{r}) = \rho_{el}(T) \cdot \vec{J}^2(\vec{r}) = \sigma_{el}(T) \cdot \vec{E}^2(\vec{r}) \qquad (1)$$

where $P_{el}(\vec{r})$ has the dimension $\left[\dfrac{W}{m^3}\right]$. $\bar{E}$ is the electric field

15   in $\left[\dfrac{V}{m}\right]$ and $\bar{J}$ is the current density in $\left[\dfrac{A}{m^2}\right]$ at any location

$\vec{r}$ of the arrangement observed. ρ_{el} denotes the electrical resistivity in $[\Omega \cdot m]$ and σ_{el} denotes the electrical conductivity of the materials used in $\left[\dfrac{S}{m}\right]$.

20   The electrical resistivity and the electrical conductivity are temperature-dependent. In the case of the glasses and refractory materials that are customarily used, they are generally negatively temperature-dependent. This means that with increasing temperature, the electrical conductivity

25   increases or the electrical resistivity decreases.

The electrical power density ρ_{el} introduced into the entire

arrangement according to equation 1 first of all leads to an increase in temperature ΔT at any point $\bar{r}$. In glass melts, the heat quantity $\dot{q}_{Pel}$ generated on account of the current in a local volume element can be dissipated again from the volume element under consideration with the aid of three mechanisms.

The first mechanism is heat conduction, which is imparted by phonons. It is assigned a $\dot{q}_{heat\ conduction}$. The second mechanism for dissipating heat from a specific volume element of the melt is radiation (heat flow $\dot{q}_{radiation}$), the exchange particles of which are photons. Finally, heat can also be dissipated from the melt by means of convection flows by a heat flow $\dot{q}_{convection}$. All three mechanisms are temperature-dependent. In general, apart from exceptions in the case of what are known as "dark" glasses, radiation is the dominant process.

After the start-up phase, a steady state is established at a defined temperature T_{eq}, in which the heat flows involved are in equilibrium with one another. In the steady state at $T = T_{eq}$, the following relationship applies:

$$\dot{q}_{Pel} = \dot{q}_{radiation} + \dot{q}_{convection} = \dot{q}_{heat\ conduction} \qquad (2)$$

After the heat quantity generated by the electric current has been dissipated from a volume element of the melt, a volume element of the material of the wall of the unit will now be considered. The refractory materials which are in contact with glass melts can be roughly divided into three groups. What are known as the HZFC (high zirconia fused cast) materials, which are cast at temperatures around 2300°C,

become soft beyond 1900°C to 2000°C. AZS (alumina zirconia silica) materials, the casting temperatures of which are 1900°C to 2000°C, do not become soft, but rather decompose at a temperature above approximately 1800°C. ZS (zirconium silicate) materials, which are sintered in pressed form during production, decompose above temperatures of just 1700°C. In any event, high excess temperatures in the refractory material lead to destruction of the latter.

At high temperatures, many refractory materials have an electrical conductivity comparable to that of glasses. In the refractory material itself, the heat quantity which is locally released by the electric current, contrary to the situation for the melt as described above, however, can substantially only be dissipated by the mechanism of pure heat conduction.

If, in the volume element under consideration, the dissipation of heat from the refractory material is lower than the heat quantity $\dot{q}_{Pel}$ generated in this volume element, the temperature will rise. In the volume element under consideration, this is associated with an increased electrical conductivity on account of the negative temperature dependency of the electrical resistivity. At constant voltage and therefore with a constant electric field E, a rise in the electrical conductivity σ_{el} (T) in accordance with equation 1 is associated with a higher electric power density $P_{el}(\bar{r})$. Accordingly, the temperature rises further. This process repeats itself until, at a relatively high temperature, a new equilibrium state is reached in the refractory material of the wall of the unit.

In a situation which can still be tolerated, all that happens is that the usual corrosion of the refractory material is accelerated on account of the higher temperature. The service life of the unit is shortened as a result. In the least

5   favorable situation, however, the system goes out of control, leading to destruction of regions of the refractory material caused by partial melting or rapid decomposition.

In the case of refractory materials, it is not just the
10   electrical resistivity in the new state which needs to be taken into consideration, but also the possibility that this resistivity may change during operation, for example as a result of the introduction of glass constituents, in particular caused by alkali metal diffusion. The material
15   becomes more electrically conductive as a result, thereby increasing the risk of local instabilities in the refractory material.

If the temperatures in the wall of the unit are higher than
20   in the melt, the melt itself functions as a cooling medium for the wall of the unit. The dissipation of heat from the wall can be improved by adapting the insulation on the outer side. The same applies to externally applied forced cooling with air.

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In addition to the advantage of improving the dissipation of heat from the wall, however, the abovementioned measures also bring with them serious drawbacks. Although the risk of excess temperatures is reduced, the cooling or reduced
30   insulation means unnecessary additional heat loss. As a result, the efficiency of the overall installation is adversely affected to a considerable extent. On account of the altered temperatures and heat flows, furthermore, flow

phenomena may occur in the   glass melt, having an adverse effect on the quality of the process.

The problem mentioned above is caused in particular by the material forming the electrode brick. This material needs to be able to withstand temperature changes, since water-cooled electrode holders are generally used. In the case of electrodes which can be pushed in further, the water supply to the electrode holder is interrupted a number of times during a tank campaign, with the result that the electrode brick is exposed to very considerable temperature gradients within a short period of time.

During the heating of the installation and/or on account of the abovementioned high temperature gradients, cracks may form in the electrode brick. These cracks generally extend radially outward from the electrode bore in the brick. Glass can penetrate into cracks of this type, thereby accelerating the corrosion of the electrode brick.

Therefore, a brick material which is as insensitive as possible to temperature changes should be selected. However, other properties of the brick, such as its resistance to corrosion from the glass melt and the electrical resistivity, should also be taken into consideration.

The ideal refractory material for an electrode brick should satisfy the following criteria. It should have only a low susceptibility to corrosion on contact with the melts used and also a high resistance to temperature changes. Moreover, the electrical resistivity in the technologically relevant temperature range should be significantly higher than that of the corresponding melt. Moreover, the material should ideally

have a high thermal   conductivity, in order to
allow even small quantities of electrical energy released to
be efficiently dissipated in the refractory material.

5   Many refractory materials, which have a high electrical
     resistivity compared to glass melts, however, have a poor
     ability to withstand temperature changes, as for example in
     the case of the zirconium silicate material ZS 1300. The
     higher the temperature gradient and its spatial profile in
10   the refractory material, the more critical this problem
     becomes. If refractory materials with a high electrical
     resistivity compared to the melt are ruled out on account of
     their poor resistance to corrosion from glass melts, it is
     necessary to employ materials which are more resistant to the
15   glass melts but under certain circumstances have a higher
     electrical conductivity.

     On account of the required resistance to corrosion from the
     melt, the ability to withstand temperature changes, the
20   availability and price, there is a very limited choice of
     suitable refractory materials.

     To avoid the risk of excess temperatures, therefore, adapting
     the electrical heating by suitably selecting the heating
25   circuit geometries, the phase positions and the electrode
     positions in the melting and/or refining unit has been the
     only viable solution known hitherto. By way of example, the
     study entitled "Elektrotechnische und wärmetechnische
     Untersuchungen zur Auswahl von Feuerfestmaterialien für
30   Elektroschmelzöfen zur Glasschmelze" [Electrical engineering
     and heat engineering tests on the selection of refractory
     materials for electric melting furnaces for glass melts] by
     H.-J. Illig et al., XI International Glass Congress, Prague

1977, anthology V, recommends that a maximum electric field strength of 4-5 V/cm should not be exceeded using typical materials for the tank. However, this imposes considerable restrictions on the way in which the installation is

5 operated.

One possible option is, for example, a switch from bottom electrodes to what are known as top electrodes, which are immersed in the melt from above and do not have to be passed

10 through a refractory structure.

In many cases, it would be desirable for the electrical heating circuits to be operated with a higher power and therefore higher voltages, in order, for example, to achieve

15 higher throughputs or to optimize the flows with regard to glass quality. If all the optimization options, in particular those presented above, have already been exhausted, in many cases the diameters of the electrode sticks are increased, in order to influence the current densities and therefore the

20 local release of energy in the immediate vicinity of the electrode. However, the electrode diameter cannot continue to be increased arbitrarily, since the size of the drilled hole in the refractory material is limited.

25 The underlying problem in the context outlined above resides in the spatially extremely nonuniform distribution of the introduction of heating power into the wall of the tank, which causes damage to the refractory material.

30 BRIEF SUMMARY OF THE INVENTION

In view of the above circumstances, therefore, it is an object of the invention to reduce the risk of damage to the

refractory material, in   particular caused by the
formation of cracks and corrosion.

A further object of the invention is to reduce local
differences in the spatial distribution of the introduction
of heating power into the wall of a unit. The term "unit" is
to be understood as meaning all arrangements in which the
melt is produced, treated and/or transported. In particular,
the term "unit" is to be understood as meaning a melting
and/or refining unit and/or a distributor system and/or a
channel system.

In this context, the reduction of local differences in the
spatial distribution of the electric field in the wall of the
unit constitutes a further object of the invention.

Moreover, it is an object of the invention to reduce local
differences in the temperature distribution in the wall.

Furthermore, it is an object of the invention to lengthen the
service life of the unit and to increase the efficiency of
the installation.

The diagrams presented in Figures 2 and 3 show results of a
mathematical simulation of the vicinity of the electrode. In
this case,

$$\rho_{elrefractory} = 2.5 \cdot \rho_{elglass}; \quad (\rho_{elglass} = 20 \ \Omega \cdot cm)$$

was predetermined as boundary conditions for the electrical
resistivities, since this is a standard ratio in many real
melting units. The diagram in Figure 2 shows the power
density at the transition between the wall of the tank and

the glass melt; the diagram   in Figure 3 shows the power
density at a depth of 5 cm in the refractory material of the
wall. Particularly critical regions, in the vicinity of which
experience has shown that damage to the refractory material
can occur, have therefore been considered.

The highest energy concentrations occur in the immediate
vicinity of the electrode, on account of the high electric
field gradient. In view of this fact, the invention achieves
the abovementioned objects, in a very surprisingly simple
way, just by means of a unit having the features of claim 1.

The invention provides a unit, in particular a melting and/or
refining unit and/or distributor system and/or channel
system, for conductively heatable melts, in particular glass
melts, which has a tank and at least one electrode, the
electrode passing through an opening in a wall of the tank so
as to be immersed in the conductively heatable melt, wherein
the unit has an apparatus for reducing the local introduction
of heating power into at least one region – adjacent to the
electrode – of the wall.

The use of the apparatus for reducing the local introduction
of heating power in at least one region - adjacent to the
electrode – of the wall advantageously reduces the local
excess introduction of heating power in this region compared
to the remainder of the wall. As a result, moreover, it is
possible to produce local differences in the spatial
temperature distribution of the wall. Therefore, the causes
of damage to the refractory material of the wall can be
considerably reduced, if not eliminated altogether, with the
aid of the invention.

Advantageous refinements of the invention are to be found in the associated subclaims.

To allow the local introduction of heating power to be reduced in a particular simple way, the apparatus according to the invention comprises at least one shielding device.

In the present context, the term "shielding device" is used in very general terms to refer to a device which can be used to reduce excess temperatures caused by a local maximum in the spatial distribution of the power density field.

The shielding device according to the invention may on the one hand be arranged in a region - adjacent to the electrode - of the wall. This advantageously allows flexible adaptation of the materials properties in the critical region of the wall.

To allow the advantageous adaptation of the materials properties in the critical region - adjacent to the electrode - of the wall to be carried out in a particularly simple way, the invention provides that the shielding device comprises an electrode brick made from a first material and at least one insulation device which adjoins the electrode brick.

In this context, the term "insulation device" relates to thermal insulation with respect to the outside.

An arrangement of the shielding device which is advantageously associated with low levels of structural outlay provides for a layered structure thereof, the electrode brick forming one layer and the insulation device forming at least one further layer.

As a result of at least one layer of the insulation device forming a holder for the electrode brick, the invention offers the advantage that cracks in the electrode brick on account of the damage mechanisms explained above do not lead to failure of the system in the apparatus according to the invention. Since the at least one layer of the insulation device in any event reliably holds the electrode brick, there is no longer any risk of failure of an entire wall region.

The electrode brick comprises at least one first refractory material. This material can be optimally adapted to the requirements for the ideal refractory material of an electrode brick. The combination according to the invention with the insulation device leads to the actual electrode brick taking up less space. Therefore, the further advantages of reduced use of this material which, although optimally matched to the requirements, is generally expensive, is combined with a considerable reduction in costs.

The insulation device comprises at least one second refractory material. This at least one second refractory material is advantageously used for thermal insulation and as a result reduces the temperature gradient in the first refractory material of the electrode brick. In this way, the demands imposed on the ability of the first refractory material of the electrode brick to withstand temperature changes are advantageously reduced to a considerable extent. Therefore, the invention counteracts the drawbacks of the refractory materials which have a high electrical resistivity compared to glass melts but a poor ability to withstand temperature changes.

With regard to the service   life of the installation,
however, it is particularly advantageous if the electrode
brick and the insulation device have a high ability to
withstand temperature changes. Moreover, preference is given
to an embodiment in which the refractory material of the
electrode brick and/or the refractory material of the
insulation device is resistant to corrosion from the melt.

The invention advantageously offers the option of using a
material with a higher electrical conductivity than that of
the at least one refractory material of the electrode brick
for the refractory material of the insulation device. This
option results from the arrangement, according to the
invention, of the insulation device in a layered structure
with the electrode brick, since the insulation device is
therefore positioned further away from the electrode.

The only restriction with regard to the electrical
conductivity is formed by the electrical conductivity or the
electrical resistivity of the glass melt itself. To ensure
disruption-free operation, the invention advantageously
provides that the electrical resistivity $\rho_{el,refractory}$ of the at
least one refractory material of the insulation device which
is in contact with the glass and of the at least one
refractory material of the electrode brick is higher than the
electrical resistivity $\rho_{el,melt}$ of the melt.

In a particularly preferred embodiment, the electrical
resistivity $\rho_{el,refractory}$ of the at least one refractory
material of the insulation device which is in contact with
the glass, in relation to the electrical resistivity $\rho_{el,melt}$
of the melt, has a value of at least

$\rho_{el,refractory} = 1.5 \cdot \rho_{el,melt}$, and the electrical resistivity of the at least one refractory material of the electrode brick in particular has a value of $\rho_{el,refractory} = 10 \cdot \rho_{el,melt}$.

5   According to the invention, advantageously for the service life of the materials used, the wall thickness d of the electrode brick is adapted to a selectable upper limit value for the electric field gradient $\Delta E_{1,2}$ at the transition from the electrode brick to the at least one layer of the

10   insulation device. If the upper limit value for the electric field gradient $\Delta E_{1,2}$ at the transition from the electrode brick to the at least one layer of the insulation device is, for example, $\Delta E_{1,2} = 5$ V/cm, it is possible to introduce a high heating power. At the same time, the materials used are

15   advantageously substantially undamaged.

To allow the electrode to be reliably pushed in further and/or to achieve stable vitrification of the melt in the gap between the electrode and the refractory material, the

20   invention advantageously provides that the width of the gap between the electrode and the refractory material b_{Sp} has a value in the range from 0 mm $\leq b_{Sp} \leq$ 30 mm.

In a particularly preferred embodiment, the width of the gap

25   between electrode and refractory material b_{Sp} has a value in the range from 2 mm $\leq b_{Sp} \leq$ 5 mm.

As well as being adapted, as described above, to a selectable upper limit value for the electric field gradient $\Delta E_{1,2}$, the

30   wall thickness d of the electrode brick, with a view to achieving a sufficient strength of the electrode brick, is also adapted to the width b of the opening in the electrode

brick. According to the invention, the wall thickness d is at least double the width b of the opening in the electrode brick.

5   In a preferred embodiment, the wall thickness d of the electrode brick is up to 500 mm.

In a particularly preferred embodiment, the wall thickness d of the electrode brick is in the range from

10 75 mm $\leq$ b $\leq$ 150 mm. Therefore, a sufficient strength and therefore service life of the electrode brick can advantageously be assured combined, at the same time, with the minimum possible use of material and therefore low costs.

15 In this context, it has proven advantageous for the height h of the electrode brick to be in the range from 20 mm $\leq$ h $\leq$ 300 mm.

The total thickness and load-bearing capacity of the
20 refractory materials of the insulation device should be taken into account when selecting the height h.

In a particularly preferred embodiment, the height h of the electrode brick is in the range from 75 mm $\leq$ h $\leq$ 150 mm.

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In addition to the advantage of providing a sufficiently high strength of the electrode brick combined with the minimum possible consumption of material and the corresponding dimensions, the machining costs should also be taken into
30 account with respect to the shape of the electrode brick. In principle, any desired shape and surface quality are possible.

In a preferred embodiment, the electrode brick is rectangular in form and therefore offers the advantage that it can be produced with particularly little outlay and therefore at advantageously low machining costs.

In the solution proposed here, the amount of refractory material used for the electrode brick is only the amount required by the electrical conditions. Therefore, during this selection, it is also possible to use a material which has a greater potential for forming defects in the glass than, for example, the refractory material of the insulation device, which is in contact with the glass. In this context, the overall throughput and therefore the dilution effect play a significant role. There are many installations in operation in which the entire base rather than just the immediate vicinity of the electrodes is made from the refractory material of the electrode brick (as in Figure 4).

According to the inventors' considerations and experience, there are in particular two preferred ways of introducing the refractory material of the electrode brick into the refractory material of the insulation device.

Firstly, the corresponding contact surfaces can be ground very cleanly, so that substantially no joints occur. Alternatively, defined joints can be filled with a glass or glass powder of poor electrical conductivity which, moreover, has a high viscosity at the desired temperatures of use, so that it cannot be flushed out by the production glass. This glass can also be considered as what is known as an alkali metal diffusion barrier for the brick materials 1 and 2. The gap may in particular be 0.5 mm to 10 mm wide, with a value

in the range from 1 mm to   2 mm having proven
advantageous. The ratio of the electrical resistivities
should preferably be $\rho_{el\ glass\ gap}/\rho_{el\ glass} \geq 10$.

5   The solution proposed here is preferably used for bottom
electrodes. Given suitable dimensioning and clamping of the
arrangement, it can also be used for side electrodes.

In particular the materials with a high zirconium silicate
10 content, such as ZS 1300 are similar materials, are suitable
for the electrode brick, since these materials have a
sufficient resistance to corrosion in most glass melts. The
materials with a high zirconium oxide content, such as for
example ZBX 950, are suitable for the insulation device in
15 contact with the glass, in which context the electrical
conductivity with respect to the glass melt must be taken
into account. If the glass attack is tolerable, it is also
possible to use AZS materials, such as ZAC 1711. All
materials which are suitable for the temperatures prevailing
20 at the interface between materials 1 and 2 are conceivable
for the second or subsequent layers of the insulation device.

In addition to the above-described apparatus for reducing the
local introduction of heating power into at least one
25 region – adjacent to the electrode – of the wall, in which
the shielding device is arranged in a region adjacent to the
electrode, in a further embodiment the invention provides for
the shielding device to be arranged in a region – adjacent to
the electrode – of the melt.

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This further option of arranging the shielding device allows
the invention to advantageously provide the option of then
also influencing the local introduction of heating power in

at least one region –   adjacent to the electrode –
of the wall if the construction of the shielding device
comprising electrode brick and insulation device in
accordance with the invention is not possible, in particular
5   for structural reasons.

Arranging a shielding device according to the invention in a
region – adjacent to the electrode – of the melt also allows
existing units to be retrofitted with a shielding apparatus
10   according to the invention, thereby achieving the associated
advantages.

To reduce the high energy densities in the immediate vicinity
of the electrode, the shielding device in accordance with the
15   second embodiment of the invention comprises a shielding
basket.

A shielding basket, as it is known, allows high energy
densities in the immediate vicinity of the electrode to be
20   reduced. In the interior of a shielding basket of this type,
the high electric field gradient which occurs in the
immediately adjacent region of the electrode and according to
equation 1 leads to the high energy concentrations in this
region, is reduced. Therefore, the introduction of heating
25   power is reduced compared to an arrangement without a
shielding basket.

To allow the shielding basket to be arranged in an
advantageous way in a region – adjacent to the electrode – of
30   the melt, the shielding basket has an opening through which
the electrode can be passed, the perpendicular through this
opening defining the axis of the shielding basket.

If the opening of the   shielding basket is arranged
in an upper boundary of the shielding basket, it is
advantageously possible to surround a large region of the
electrode by the shielding basket with a simple structure. In
5   a preferred embodiment, the shielding basket is arranged
coaxially with respect to the electrode. It is in this way
possible for the greatly excessive values for the electric
field gradient and therefore for the introduction of heating
power and the temperature, which are otherwise present in the
10   region adjacent to the electrode, to be uniformly reduced.

This advantage can in particular be exploited to a
considerable extent if the shielding basket is rotationally
symmetrically in form. The axis of symmetry in this case
15   forms the axis of the shielding basket. In addition to a
circular configuration, however, an oval configuration of the
shielding basket in a plane perpendicular to its axis also
offers the abovementioned advantages.

20   In general, the shielding basket may also have a plurality of
sides, in particular with sharply defined transitions,
although these transitions may also be rounded. In this
context, the variant which can be produced most efficiently
under given conditions of an optionally existing installation
25   is to be preferred. The shielding basket may in particular be
composed of a plurality of parts which are connected to one
another, in particular by screw connection, welding or other
joining processes.

30   An advantageously simple structural configuration of the
shielding basket is produced if the upper boundary of the
shielding basket is formed integrally. In this case, by way
of example, a plate with an opening for the electrode can be

used as the upper boundary of the shielding basket. Then, the melt, given a suitable configuration of the lateral boundaries of the shielding basket, can be more or less enclosed in the basket region.

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If virtually unimpeded glass exchange is desired, the invention provides a shielding basket which has two rims, which can be connected by elements, at least one rim forming the upper boundary. This embodiment comprises, for example, a cage-like structure made up of two rings which are connected to one another by webs.

The radius of the rings may in this case differ. By way of example, one rim may be arranged at a greater distance from the opening through which the electrode passes through the wall of the unit. This rim may in particular have a smaller radius than the other rim, which then forms a lower boundary. The webs then constitute lateral boundaries of the basket, so as to form a conical shielding basket.

The rims and the elements connecting them may, however, also be dimensioned and arranged in any other desired way depending on the demands imposed on the spatial distribution of the introduction of electrical power which is to be achieved.

According to a preferred embodiment, the longitudinal axis of the elements forms an angle W with that surface, facing the melt, of the region - adjacent to the electrode - of the wall.

The angle W in particular has a value in the range from $0° < W \leq 90°$. An advantageous shielding action can be achieved in particular if the angle W has a value in the range from $30° \leq W \leq 60°$.

To avoid possibly structurally complex securing of the shielding basket in the refractory material, the invention advantageously provides for it to be possible for the shielding basket to be secured to the electrode. In this case, it is assumed that there is no need for the electrode to be pushed further in during a tank campaign and that the electrode and the basket can be suitably protected from oxidation for example during heat-up. If the shielding basket is secured to the electrode, the electrode is to be installed at the final setting depth.

If, in particular on account of the risk of the electrode stick breaking off during operation or on account of problems with oxidation prevention during the heat-up phase, the possibility of pushing the electrode body further in needs to be retained, the shielding basket can be arranged in the glass melt without direct contact with the electrode body.

The problem of an excessively high current density in the intermediate space can be avoided if the shielding basket is connected to the outer region in a suitable way through the refractory wall. In this case, the heating electrode and the basket are at the same electrical potential on the cold outer side.

Securing the shielding basket to the electrode body itself advantageously makes it possible to use the shielding basket even for what are known as top electrodes, which are immersed

in the glass melt from above. In the latter case, this is done in order to deliberately set the release of power in the vicinity of the electrode stick.

5 Otherwise, the shielding basket according to the invention is preferably used for bottom electrodes. In order to advantageously allow use even with side electrodes, moreover, the invention provides the option of configuring the shielding basket such that it can be secured to the wall.

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Furthermore, it is also conceivable for suitable apparatuses, such as wedges or balls, which allow the electrode to be pushed in further and also allow intimate contact between the electrode stick and basket, to be fitted to the "basket"

15 itself. If these apparatuses are used, however, according to the invention the corrosion to the corresponding refractory metal caused by the glass melt is very low.

To enable particularly high current densities to be

20 introduced for efficient heating of the melt without endangering the materials used, the invention provides for the shielding basket to comprise Mo and/or W and/or SnO_2 and/or at least one precious metal and/or at least one alloy of the abovementioned materials and/or high-temperature-

25 resistant steels.

On account of the design of the basket, in particular its contour, its height or further parameters, a different release of power in the vicinity of the electrode can be set,

30 which has a direct effect on the flow field of the overall arrangement.

With a view to achieving a sufficient mechanical strength of

the shielding basket combined, at the same time, with a high efficiency with regard to ensuring a uniform spatial distribution of the introduction of heating power into the wall, it has proven particularly advantageous to use specific dimensions for the corresponding lengths.

The invention in particular provides for the ratio of the length of the electrode body L_{EK} which is immersed in the melt to the height H_K of the shielding basket to have a value in the range from $1 \leq L_{EK}/H_K \leq 20$. In a particularly preferred embodiment, the ratio of the length of the electrode body L_{EK} which is immersed in the melt to the height H_K of the shielding basket has a value in the range from $2 \leq L_{EK}/H_K \leq 5$.

The ratio of the outer radius R_K of the shielding basket to the radius R_{EL} of the electrode body advantageously has a value in the range from $2 \leq R_K/R_{EL} \leq 15$. According to a particularly preferred embodiment, the ratio of the outer radius R_K of the shielding basket to the radius R_{EL} of the electrode body has a value in the range from $3 \leq R_K/R_{EL} \leq 7$.

The ratio of the distance D_{HK} between two electrodes to the outer radius R_K of the shielding basket according to the invention advantageously has a value in the range from $3 \leq D_{HK}/R_K \leq 500$. According to a particularly preferred embodiment, the ratio of the distance D_{HK} between two electrodes to the outer radius R_K of the shielding basket has a value in the range from $20 \leq D_{HK}/R_K \leq 80$.

The width l_K of the upper rim of the shielding basket according to the invention is in the range from $0 \leq l_K \leq R_K$. According to a particularly preferred embodiment, the width

l_K of the upper rim of the shielding basket is in the range from $0 \leq l_k \leq 1/3 \cdot R_K$.

The width a of the gap between electrode body and inner boundary of the opening in the shielding basket is in the range from $0 \leq a \leq 50$ mm. According to a particularly preferred embodiment, the width a of the gap between electrode body and inner boundary of the opening in the shielding basket is in the range from 0 mm $\leq a \leq 30$ mm.

The material thickness d_K of the components of the shielding basket is in the range from 5 mm $\leq d_K \leq 50$ mm. The width b_{Sp} of the gap between electrode body and inner boundary of the opening in the wall is in the range from 1 mm $\leq b_{Sp} \leq 30$ mm.

According to a particularly preferred embodiment, the width b_{Sp} of the gap between electrode body and inner boundary of the opening in the wall is in the range from 2 mm $\leq b_{Sp} \leq 5$ mm.

The thickness D_{FF} of the material of the wall which is in contact with the melt is in the range from 50 mm $\leq D_{FF} \leq 500$ mm. According to a particularly preferred embodiment, the thickness D_{FF} of the material of the wall which is in contact with the melt is 100 mm $\leq D_{FF} \leq 300$ mm.

To ensure reliable operation of the melting and/or refining unit according to the invention using at least one shielding basket, the invention advantageously provides that the ratio of the electrical resistivity $\rho_{el,\text{refractory}}$ of the at least one refractory material of the wall and/or of the at least one refractory material of the electrode brick and/or of the at

least one refractory material of the insulation device to the electrical resistivity $\rho_{el,melt}$ of the melt has a value of from 1 to 20.

According to a particularly preferred embodiment, the ratio of the electrical resistivity $\rho_{el,refractory}$ of the at least one refractory material of the wall and/or of the at least one refractory material of the electrode brick and/or of the at least one refractory material of the insulation device to the electrical resistivity $\rho_{el,melt}$ of the melt has a value of from 1.5 to 5.

The use of a shielding basket allows the shielding device according to the invention to be of less sensitive construction compared to the insulation device. Therefore, smaller lower limit values and therefore a wider range for the parameter $\rho_{el,refractory}/\rho_{el,melt}$ are possible for the embodiment with a shielding basket. This means that a wider choice of materials is advantageously available for the refractory materials that can be used for a given melt.

The invention also encompasses the possibility of realizing a combination of electrode brick and insulation device with a shielding basket in an advantageous way, in order thereby to increase the number of possible parameters so as to set an optimum spatial distribution of the introduction of electrical heating power.

For efficient operation of the melting and/or refining unit, according to the invention the temperature T advantageously has a value in the range from 500°C $\leq$ T $\leq$ 3000°C. In a particularly preferred embodiment, the temperature T has a

value in the range from $800°C \leq T \leq 1900°C$. The temperature information relates to the components which are heated, i.e. in particular to the melt, the tank, the electrode and the shielding device.

According to the invention, the current loading i has a value of from $0.05 \text{ A/cm}^2 \leq i \leq 20 \text{ A/cm}^2$. The current loading information relates to metal parts, i.e. in particular to the electrode and/or the shielding basket and/or the electrode/shielding basket intermediate space.

The invention advantageously allows particularly high current loadings i. In a particularly preferred embodiment, the current loading i has a value in the range from $0.1 \text{ A/cm}^2 \leq i \leq 3 \text{ A/cm}^2$.

To make the apparatus according to the invention for reducing the local introduction of heating power in at least one region – adjacent to the electrode – of the wall as versatile as possible in use, the invention advantageously provides for the at least one electrode to be a bottom electrode and/or a side electrode and/or a top electrode.

Furthermore, the invention relates to the use of an apparatus for reducing the local introduction of heating power in at least one region – adjacent to the electrode – of the wall, the apparatus being designed in particular as described above, during operation of a unit for conductively heatable melts, in particular for glass melts.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The invention is explained in more detail below on the
basis of exemplary embodiments and with reference to the
accompanying drawings. In the drawings, identical components
are denoted by the same reference designations. In the

5   drawings:

Fig. 1   diagrammatically depicts an excerpt from a
                wall of a melting and/or refining unit having an
                electrode,

10

Fig. 2   shows the power density distribution around an
                electrode at that surface of the wall of the
                melting and/or refining unit which faces the melt,

15   Fig. 3   shows the power density distribution around an
                electrode at a depth of 5 cm measured from the
                surface of that side of the wall of the melting
                and/or refining unit which faces the melt,

20   Fig. 4   diagrammatically depicts a longitudinal
                section through an electrode brick,

Fig. 5   diagrammatically depicts a longitudinal
                section through a first embodiment of a shielding
25   device according to the invention,

Fig. 6A   diagrammatically depicts a ~~longitudinal~~
                ~~section through and~~ plan view of a second
                embodiment of a shielding device according to the
30   invention,

Fig. 6B   is a longitudinal section through the shielding
                device of Fig. 6A taken through lines AA,

Fig. 7A   diagrammatically depicts a ~~longitudinal section through and~~ plan view of a further embodiment of a shielding device according to the invention,

Fig. 7B   is a longitudinal section through the shielding device of Fig. 7A taken through lines BB,

Fig. 8   diagrammatically depicts the geometric dimensions of the shielding device according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1 illustrates a typical structure of an electrode for heating conductively heatable melts based on the example of a glass melt. The electrode 20 is fitted into an opening in a wall 10 of a melting and/or refining unit, in such a manner that electric current can be fed via the electrode 20 into a glass melt 30.

The electrode 20 comprises an in particular water-cooled electrode holder, in which the actual electrode body is secured in a suitable form. The electrode holder is externally connected to a heating circuit transformer via a cable. The electrode 20 comprising electrode holder and electrode body is introduced into the melt 30 through the wall 10, which is constructed from refractory materials, with the setting depth being determined by the particular type of glass. In this context, in particular the vitrification and crystallization properties, the required process temperatures and the thermal conductivity of the material of the wall 10

are important parameters.

Curve 1 in the diagram presented in Fig. 2 shows the power
density curve around an electrode 20 in a wall 10 directly at
that surface 18 of the wall 10 which faces the glass melt 30.
The figure plots the power density in W/m^3 against the
distance in m from the electrode 20. The figure illustrates
the region around an electrode E1 for an arrangement in which
a second electrode E2 is located in the direction of the
positive distances, i.e. toward the right in the diagram. The
plotted values are the result of a mathematical simulation of
the area surrounding the electrode, in which

$\rho_{elrefractory} = 2.5 \cdot \rho_{el,glass}$; ($\rho_{elglass} = 20\ \Omega \cdot$ cm) was
predetermined as a boundary condition for the electrical
resistivities.

The greatest power density is introduced into the surrounding
material in the immediate vicinity of the electrode E1.
Accordingly, the highest energy densities and therefore the
highest temperatures will occur in these regions. The power
density decreases considerably at increasing distance from
the electrode. Even after just about 4 cm, it has dropped to
approximately half its original value. This means that during
conventional operation of the installation, extremely high
gradients of the power density and therefore of the variables
associated with the power density occur in the vicinity of
the electrode. Particularly large amounts of energy are in
this case released in the region of the main direction of
flow, i.e. on that side of the electrode E1 which faces the
adjacent electrode E2, on the right-hand side in the diagram.

The diagram presented in Fig. 3 illustrates the corresponding
data on the power density curve around an electrode E1 at a

depth of 5 cm, calculated   from that surface 18 of the
wall 10 which is in contact with the melt. As demonstrated by
the data in curve 1, even at a depth of 5 cm within the wall
10, the highest power density values are reached in the

5   immediate vicinity of the electrode.

The considerable drop in the power density at increasing
distance from the electrode E1 at distances of less than
about 5 cm, in addition to the higher resistivity of the

10   electrode brick material compared to the glass melt, is also
attributable to the cooling of the electrode, in particular
the water cooling of the electrode holder and the possibility
of forced convection of cooling air on the outer side of the
electrode brick. As shown in curve 1, these cooling measures

15   are insufficient for breaking down strong gradients in the
power density in the vicinity of the electrode with a
conventional arrangement.

To reduce the risk of damage to the refractory material of

20   the wall 10, in particular caused by the formation of cracks
and corrosion, according to the invention local differences
in the spatial distribution of the introduction of power into
the wall are reduced. According to a first embodiment of the
invention, a shielding device which is arranged in a

25   region – adjacent to the electrode 20 – of the wall 10 is
used for this purpose.

Fig. 4 shows a conventional structure of an electrode brick
11. Electrode bricks are customarily designed in the form of

30   a monolithic block. By contrast, the invention, as
illustrated in Fig. 5, provides for the shielding device 15,
according to a first embodiment, to have an electrode brick
11 which is held by an insulation device.

In the example illustrated, the insulation device comprises a first layer 12, which also serves as a holder for the electrode brick 11, and a second layer 13, which forms a sandwich-like structure with the two layers of the electrode brick 11 and the first insulation layer 12.

The refractory materials 12 and 13 located around the actual electrode brick 11 serve as thermal insulation and thereby reduce the temperature gradient in the material of the actual electrode brick 11. Since the materials of the layers 12 and 13 additionally perform a supporting function, cracks which may under certain circumstances occur in the electrode brick 11, with the structure according to the invention, advantageously do not lead to the entire system failing.

A material which has a good ability to withstand temperature changes can be used for the refractory material 12. There is generally a selection of materials available which are additionally resistant to corrosion with respect to the glass melts 30 used. Moreover, the material 12 may have a significantly higher electrical conductivity, i.e. a reduced electrical resistivity, than the material of the actual electrode brick 11, since it is positioned further away from the electrode 20. The only restriction on the material of the layer 12 is formed by the electrical conductivity of the glass melt.

The inventors' practical experience has demonstrated that for reliable operation the condition $\rho_{el,refractory} = 1.5 \cdot \rho_{el,glass}$ should be satisfied. The dimension d is selected in such a way that the electric field gradient $\Delta E_{1,2}$ in the region where the materials of the electrode brick 11 adjoin the

first insulation layer 12   does not exceed a value of

approximately 4 to 5 V/cm. The height of the electrode brick

h is generally selected to be from 20 to 300 mm. The width of

the gap b limits the lower value for the dimension d, the

5   dimension d being at least double the gap width b.

In addition to the above-described advantages of the first

embodiment of a shielding device 15 according to the

invention, the sandwich-like structure illustrated in Fig. 5

10   offers the further positive effect that the materials of poor

conductivity, such as in this case the materials of the

electrode brick 11, are generally very expensive, and if

their use is minimized in accordance with the invention, it

is possible to save on high costs.

15

Fig. 6 diagrammatically depicts a shielding device 25 in

accordance with a second embodiment of the invention, which

is arranged in a region - adjacent to the electrode 20 - of

the melt 30.

20

This shielding device 25 comprises a shielding basket 22,

which has an opening 26 through which the electrode 20 can be

passed. The opening 26 in the shielding basket 22 is arranged

in an upper boundary 24 of the shielding basket.

25

In the example shown, the shielding basket 22 is cylindrical

in form, with the boundary 24 delimiting the shielding basket

22 with respect to the melt 30 in the upward direction, while

the lateral boundary 23 closes off the shielding basket 22 as

30   seen in the radial direction from the electrode 20. In this

embodiment, the melt 30 is substantially enclosed in the

interior of the shielding basket 22.

Fig. 7 illustrates a further   embodiment of a shielding
basket. A first rim 27 forms the upper boundary 24 of the
shielding basket. A second rim 28 forms the lower boundary of
the shielding basket 22. The two rims 27 and 28 are connected
5   to one another by webs 29. In this variant, virtually
unimpeded exchange of the melt 30 between the interior of the
shielding basket 22 and the region outside the shielding
basket 22 is possible.

10   The high gradient of the electric field which occurs in the
immediate vicinity of the electrode 20 leads – as illustrated
in curve 1 of the diagrams in Figures 2 and 3 – to an uneven
distribution of the power density and in particular to excess
introduction of power in this region. This excess
15   introduction of power can be reduced by the use of a
shielding basket according to the invention. This is
illustrated in curves 2, 3 and 4 in the abovementioned
diagrams.

20   The simulations of the results illustrated by curves 2, 3 and
4 were carried out for a design of shielding basket 22
corresponding to the illustration shown in Fig. 6, with an
external diameter of 250 mm. The distance from the inner
boundary of the opening 26 in the shielding basket to the
25   electrode was varied for the curves 2, 3 and 4.

If the inner boundary of the opening 26 of the shielding
basket 22 is arranged at a distance of 28 mm from the
electrode (curve 4), a considerable reduction in the local
30   introduction of power density in the immediate vicinity of
the electrode by about a third of the value without a
shielding basket is already achieved. If the distance between
the inner edge of the opening 26 of the shielding basket and

the electrode is reduced   further (curve 3, curve 2),
the introduction of power density into the immediate vicinity
of the electrode 20 decreases further.

5   The highest energy reduction compared to an electrode without
a shielding basket in the immediate vicinity of the electrode
20 itself is achieved if the shielding basket 22 is secured
directly to the electrode stick. This is illustrated by curve
2 in the diagrams presented in Figs 2 and 3.

10

The gradient of the electric field and therefore the power
density are boosted at the outer edge of the shielding basket
22. The energy released in this region is greater than with
the corresponding arrangement without basket 22.

15   Nevertheless, even this increased introduction of power
amounts to only a fraction of the values which are released
in the immediate vicinity of the electrode without a basket.
This slight increase in the power density in the region of
the outer edge of the basket is therefore in no way critical.

20   It does not present any danger to the refractory material of
the wall 10. In particular, in this region there is a larger
volume available for dissipating the heat which is generated.
Therefore, any energy which may be fed into the refractory
material can be quickly dissipated.

25

If the possibility of moving the electrode body further in
needs to be preserved, the shielding basket 22 must not be in
direct contact with the electrode 20. The possibility of
moving the electrode body further in offers the advantage

30   that it is possible to react flexibly to the risk of the
electrode stick breaking off during operation or to problems
with prevention of oxidation while the installation is being
heated up. In this case, a certain distance has to be

maintained between the   electrode stick surface and
the inner edge of the basket 22.

5

The problem of an excessively high current density in the
intermediate space between shielding basket 22 and electrode
20 can be avoided if the shielding basket 22, as illustrated
in the figures in the form of a possible electrical
10   connection 40, is connected to the outer region 50 in a
suitable way through the wall 10.

Fig. 8 illustrates relevant geometric variables of an
arrangement according to the invention of the shielding
15   device 25 for two adjacent electrodes 20. The abovementioned
distance a between the electrode 20 and the inner edge of the
basket 22 is indicated in this illustration. The smaller the
distance a is selected to be, however, the higher the current
densities in this transition region become.

20

The current flows on the path of least resistance from an
electrode E1 of a heating circuit to the next electrode E2.
Therefore, the maximum permissible current densities for the
glass quality should be taken into account when selecting the
25   distance a. In particular the formation of bubbles, the
dissolution of glass and possible corrosion of the material
of the electrode and/or of the shielding basket play a role
in respect of the glass quality.

30   The two electrodes 20 are at a distance D_{HK} from one another
which indicates the length of the heating circuit. An
electrode body has a radius R_{el}, and the length of the
electrode body in the glass is L_{el}. The electrode 20 is

arranged in an opening in the wall 10, with the width of the gap between electrode body and the inner boundary of the opening in the wall 10 being denoted by b_{Sp}. The thickness of the refractory material which is in contact with the glass

5   melt is denoted by D_{FF}.

A shielding basket 22 is arranged around the electrode 20. The outer radius of the shielding basket is R_K, which is at the same time the greatest longitudinal axis in the heating

10   direction. The height of the shielding basket is H_K. The width of the upper rim of the shielding basket 22, which is also referred to as the upper collar, is denoted by l_K. The material thickness of the components of the shielding basket 22 is d_K. In the embodiment shown, the longitudinal axis of

15   the elements 29 includes an angle W with that surface 18, facing the melt, of the region - adjacent to the electrode 20 - of the wall 10.